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Robot Based Solar Panel Cleaning System

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Abstract
Solar energy is one of the most used energy for generating electricity nowadays. During generation the energy reduction is caused by environmental factors like dirt, dust etc. The proposed robot based solar panel cleaning system improves the voltage level which intern increases overall efficiency of solar panel. This research focus on designing, monitoring and implementation of solar panel cleaning, uses water for protecting panel from scratches and cooling. This system mainly consists of dust sensor, Arduino Nano, motor drives, Rx/Tx module, ultrasonic sensor and water pump. The dust sensor detects the dust, Arduino monitors the circuit, Tx/Rx module sends and receive signals. Ultrasonic sensor keeps the robot in panel's perimeter and motor drives are control robot movement and water pumping.

Keywords: *Arduino Nano; Dust sensor; Tx/Rx module; Motor drive; Ultrasonic sensor.*

1. Introduction
Solar energy is the radiant energy and it is the most readily available source of energy. Solar PV panel is the device which is used to absorb the sunlight and convert them into electricity. Whereas solar panels allow photons to hit electrons those are free from Atoms by generating a flow of electricity. Solar cells yield in a few sections of the world is cut by more than 25% because of airborne particles and tidy, to maintain optimal efficiency, solar panels require regular cleaning to remove dust and dirt on their surfaces. (Md. Rawshan Habib et al., 2021; Ram Jatan Yadav et al., 2022; Babu K et al., 2018).

1.1. Solar Panel Cleaning System Utilizes a Two-Step Technique
1. **In this paper the Solar Panel Cleaning System Utilizes a Two-Step Technique**: first, an exhaust fan removes surface dust, including four types of sands, followed by a soft cloth wiper for thorough cleaning without water, safeguarding against scratches. Fabricated with readily available components like solar panels, Arduino Uno, DC gear motor, and buck boost converter, ensuring accessibility. [1]
2. The proposed Automatic drive system aligns with solar panel length, control by a base circuit triggering the cleaning mechanism via switches, enhancing panel efficiency for electricity generation. Inspired by FDM 3D printing precision, the design simplifies cleaning with high accuracy. Targeting domestic solar panel installations like houses and buildings, it addresses limitations in energy consumption, particularly in assemblies of 10-20 panels. [2]
3. The proposed solar panel cleaning system consists of a cleaning robot and a carrier robot. The carrier robot transports the cleaning robot across panels, allowing it to cover the entire surface. Equipped with a brush, the cleaning robot removes dirt and dust, controlled by a Arduino. Designed for efficiency, the system simplifies cleaning across multiple panels, reducing labor and costs. Additionally, the system investigates the impact of dust on solar panel performance and proposes an auto cleaning robot for enhanced maintenance. [3]

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2. Method

This system works on the principle of dust sensing, which primarily consists of two modules: a transmitter module and a receiver module. The transmitter circuit includes a dust sensor, an Arduino Nano, and a buzzer. The receiver circuit comprises an Arduino Nano, a water pump, an ultrasonic sensor, and motor drives. The dust sensor is programmed to detect dust every minute. If dust is detected, the buzzer sounds to indicate its presence, and data is transmitted from the transmitter circuit to the receiver circuit. The receiver module is integrated into the cleaning robot. The robot operates at 12V, powered by four lithium-ion batteries connected in series (each with a voltage of 3.7V). The Arduino Nano on the receiver circuit controls the robot's movements and the water pump through two motor drives. The first motor drive manages the robot's forward and backward motion, while the second motor drive controls the water pump and wiper. An ultrasonic sensor is attached to the robot to ensure that it remains on the solar panel surface. The sensor is calibrated to maintain a gap of 1-1.5cm between the robot and the panel. If the robot attempts to move out of the panel's perimeter, the distance between the panel and the ultrasonic sensor is measured to prevent the robot from leaving the cleaning area, shown in Figure 1, Figure 2 & Figure 3.

2.1. Figures

1(a) 1(b) 1(c)

Figure 1(a, b, c) Solar Panel Before Cleaning

Figure 2 Solar Panel While Cleaning

Figure 3 Solar Panel After Cleaning

3. Results and Discussion

3.1. Results

After solar panel get cleaned and output voltage level increased, shown in Table 1.

Table 1 Comparison of Solar Panel Voltages Before and After Cleaning

SL.NO	NO. OF DAYS EXPOSED TO DUST	VOLTAGE BEFORE CLEANING	VOLTAGE AFTER CLEANING
1	1DAY	13.72	13.74
2	2DAYS	13.69	13.73
3	3DAYS	13.56	13.71
4	4DAYS	13.45	13.70
5	5DAYS	13.37	13.70

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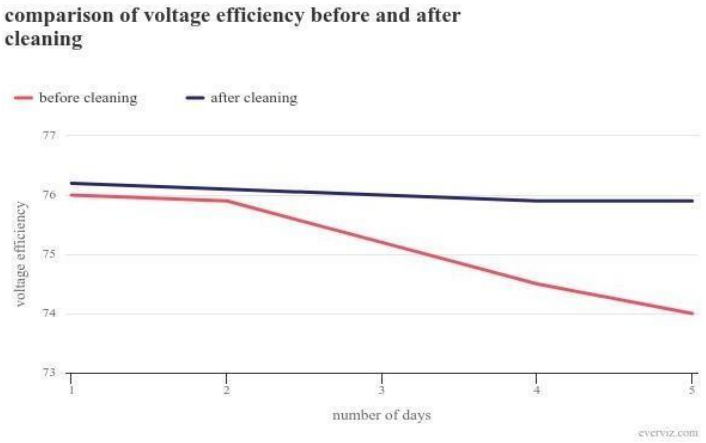
3.2. Discussion

From the Table 1, it can be concluded that the solar panel cleaning system maintains nearly the same voltage output after each cleaning cycle. However, it is evident that the voltage gradually decreases with an increase in the number of days the solar panels are exposed to environment. Specifically, the voltage reduction is observed to be 0.03V after one day, 0.16V after two days, 0.27V after three days, and 0.35V after four days. This trend indicates a proportional increase in the voltage margin as the exposure duration extends. This observation provides the importance of regular cleaning and maintenance of solar panels for maximizing efficiency and minimizing voltage losses (Graph 1, Graph 2).

3.3. Graphs

Graph 1 Voltage Comparison Before and After Cleaning



Graph 2 Comparison of Voltage Efficiency Before and After Cleaning

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